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Reinforcing patient safety in Intraoperative electron radiotherapy. Impact of different tools

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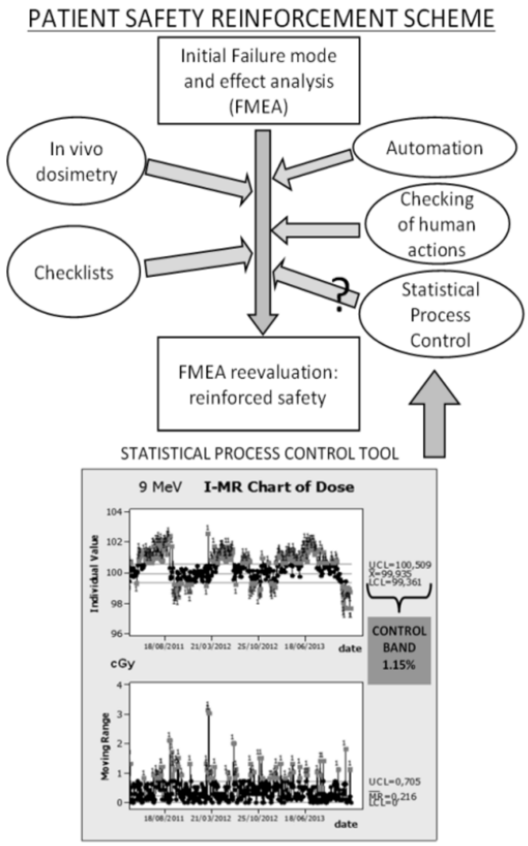
Purpose/Objective: European authorities and scientific societies have advised that patient safety be analyzed and adequately managed. Thus, we present a set of tools and measures we studied in order to reinforce patient safety in Intraoperative electron radiotherapy (IOERT).

Materials and Methods: We performed a Failure mode and effect analysis (FMEA) which was used to centralize all the information regarding patient safety in IOERT. Safety elements included tools such as in vivo dosimetry in 40 valid cases, statistical process control (SPC) of electron beam monitoring, checklists design and implementation, and other insights unveiled by the FMEA like the necessity for checking several actions taken by involved professionals. In vivo dosimetry was performed with reinforced MOSFETs model TN-502RDM-H (Best Medical Canada Ltd., Ottawa, Canada). Electron beam monitoring was carried out with the daily checking device, Daily QA Check 1090 (Sun Nuclear Corporation, Melbourne, USA), which controlled our Elekta Precise linac (Elekta AB, Stockholm, Sweden) used for the IOERT treatments. Our checklists were related to procedures and materials managed by anesthesiologists, surgeons, radiation oncologists, nurses, radiation therapists, and medical physicists. They were divided in blocks and timeouts.

Results: The FMEA was a very fruitful tool to identify all potential risks and allocate measures in order to reduce such risks and reinforce patient safety. In vivo dosimetry confirmed our treatments as correct, with a delivered measured absorbed dose of 93.8% on average (with a standard deviation of 6.7%), compared to an expected dose to the tumor bed between the prescribed dose (90%) and the maximum dose (100%). SPC led to uneasy-to-implement conclusions due to its high sensitivity compared to linac output fluctuations. As an example, absorbed dose delivered with 9 MeV beams would require to be adjusted one quarter of the times they are checked in order to achieve a feasible control band of 1.15% calculated with their SPC. Checklists were feasible and easy to write, but require a strong commitment of the multidisciplinary team to be operative, namely the strict fulfillment of blocks at timeouts. Other necessary elements are double checking of human decisions, also easy to implement, and requests for automation whenever possible, which need engagement of companies to be solved.



Conclusions: FMEA can be the main tool to identify opportunities for patient safety reinforcing, and can produce a central board to which fit risk reduction elements and actions. As examples, these measures and tools can be an in vivo dosimetry program, checklists, checking of human decision-making, and automation of several processes. Nevertheless, SPC needs further research before being integrated. This approach can be extended to other radiotherapy procedures.

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Optimizing the planning parameters to obtain the lowest monitor units in lung stereotactic body radiation therapy

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Purpose/Objective: The increasingly attractive stereotactic body radiation therapy (SBRT) for stage I lung cancer is always accompanied by a large amount of monitor units (MU), particularly with a high dose fraction scheme. The study aims to find the optimal planning parameters in the treatment planning system optimizer to get the lowest monitor unit (MU) in lung SBRT.

Materials and Methods: Fourteen patients suffered from peripheral or central stage I Non-Small Cell Lung Cancer (NSCLC) were enrolled. The upper objective of planning target volume (UO-PTV) and two other MU constraining objectives (strength and max MU) in the optimizer were adjusted to investigate their effects on MU numbers, target coverage and organs at risk (OARs) sparing. Firstly, the UO-PTV (with low, medium and high priority) was compared to find the lowest MU and superior OARs sparing; Secondly, the effect of strength (settings were 25, 50, 75 and 100) on the MU numbers was investigated based on the beneficial UO-PTV setting; Finally, the feasible priority and strength settings were then employed to investigate the impact of max MU (settings were 25%, 50%, 75%, 85%, 100%) on the MU numbers.

Results: We found that the planning parameters in the optimizer influenced the MU numbers in a priority, strength and max MU-dependent manner. The MU numbers displayed a decreasing trend with the UO-PTV increasing. The MU numbers with low, medium and high priority for the UO-PTV were 428±54, 312±48 and 258±31 MU/Gy, respectively. The high priority setting for UO-PTV also spared the heart and cord while maintaining comparable PTV coverage than the low and medium priority group. The strength and max MU settings in the MU constraining objective also influenced the MU numbers. The MU numbers tended to decrease with the strength increasing and max MU setting decreasing. With the maximum strength of 100, the MU numbers reached its minimum while maintaining comparable or improved dose to the normal tissues. It was also found that the MU numbers continued to decline at 85% and 75% max MU setting, but no longer to decrease at 50% and 25%. Combined with the high priority for UO-PTV and MU constraining objectives, the MU numbers can be decreased to 223±26 MU/Gy.

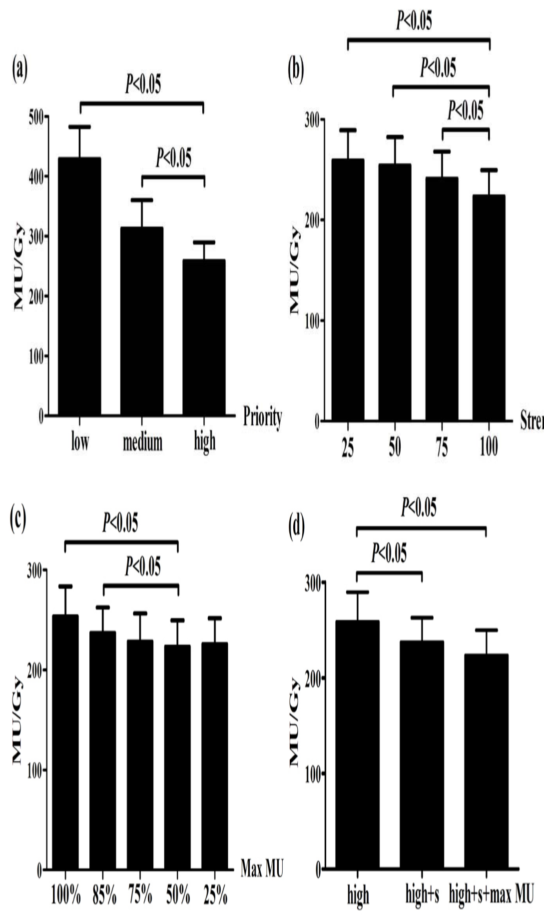

Figure 1. Effect of planning parameters on the MU numbers. (a) priority, (b) strength, (c) max MU. (d) MU comparison between high priority group, high priority+s group and high priority+s+max MU group. high= high priority, s=strength. Strength was set to 100 and max MU was set to 50%.

Table 1 Dosimetric comparison of PTV and OARs for different planning parameter settings

Structure&Parameter	Unit	Low	Medium	High	High+MU	*P* value
PTV D_{min}	%	92.5±1.0	93.0±1.6	93.2±1.3	92.9±1.2	0.097
PTV D_{max}	%	124.1±1.4	123.5±1.3	123.3±1.0	123.1±1.6	0.003
PTV D_{mean}	%	108.6±1.5	108.7±1.4	108.7±1.3	108.8±1.3	0.110
Aorta D_{max}	Gy	12.4±11.4	12.0±11.2	11.8±11.3	11.6±11.4	0.032
Esophagus D_{max}	Gy	8.2±5.6	7.8±5.4	7.8±5.4	7.5±5.7	0.047
Bronchial tree D_{max}	Gy	11.0±11.1	11.2±11.3	11.2±11.0	10.9±11.2	0.145
Heart D_{max}	Gy	12.8±14.9	12.7±14.7	12.1±14.2	12.6±15.3	0.007
Cord D_{max}	Gy	7.6±4.5	7.0±4.3	6.6±4.2	6.5±3.7	0.002
Lung V_5	%	10.7±4.0	10.6±4.0	10.6±4.1	10.6±4.1	0.307
Lung V_{10}	%	5.9±2.9	5.8±2.9	5.8±2.9	5.8±2.9	0.079
Lung V_{20}	%	2.2±1.5	2.2±1.5	2.2±1.5	2.2±1.5	0.543
Lung mean	Gy	201.6±77.6	199.2±77.9	198.8±78.4	199.0±78.6	0.004
D_{2cm}	%	49.8±4.1	49.3±4.5	49.6±4.4	49.6±4.2	0.427
$CI_{100\%}$		0.99±0.04	0.97±0.01	0.97±0.02	0.97±0.01	0.004
$CI_{50\%}$		4.25±0.51	4.21±0.51	4.23±0.50	4.25±0.49	0.111

Abbreviations: Low = low priority, Medium = medium priority, High = high priority. High + MU = high priority combined with MU constraining objective. P<0.05 stands for statistically significant.

Conclusions: The priority of UO-PTV, MU constraining objective in the optimizer impact on the MU numbers in lung SBRT. Giving high priority to the UO-PTV, setting the strength to 100 and the max MU to 50% in the MU objective achieves the lowest MU numbers while maintaining comparable or improved OAR sparing.